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Research Document 2011/006 | **Document de recherche 2011/006**

Newfoundland and Labrador Region | **Région de Terre-Neuve et Labrador**

New Estimates of Whole Weight, Percent Females and Fecundity for Use in the Determination of Conservation Status of Atlantic Salmon (*Salmo salar*) in Assessed Rivers in the Bay St. George Area (SFA 13)

Nouvelles estimations du poids brut, du pourcentage de femelles et de la fécondité devant servir à déterminer l'état de conservation du saumon atlantique (*Salmo salar*) dans les rivières étudiées dans le secteur de la baie St-George (ZPS 13)

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ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)

Canada

Correct citation for this publication:
La présente publication doit être citée comme suit :

Veinott, G and Cochrane, N. 2011. New Estimates of Whole Weight, Percent Females and Fecundity for Use in the Determination of Conservation Status of Atlantic Salmon (*Salmo salar*) in Assessed Rivers in the Bay St. George Area (SFA 13). DFO Can. Sci. Advis. Sec. Res. Doc. 2011/006. iv + 9 p.

ABSTRACT

Data available for estimating whole weight, percent females and fecundity in Atlantic Salmon stocks in rivers in the Bay St. George area of insular Newfoundland were reviewed. New estimates, which include data collected since the moratorium, of these stock's biological characteristics were compared to values currently used to determine the status of these stocks. In general, the new estimates of whole weight and percent female were lower than the current default values. A new estimate of fecundity for small (<63 cm) salmon (1880 eggs/kg) was higher than the default value of 1540 eggs/kg. For the rivers that were assessed in 2008 the new values resulted in an increase in percent conservation achieved for Harry's River and Middle Barachois Brook and declines for Flat Bay Brook, Fishels River, and Robinsons River. Overall there is a lack of river specific and year specific biological data and in particular fecundity data available for these rivers. Improvements in estimates of percent conservation achieved can only be made with additional sampling of these populations.

RÉSUMÉ

Les données disponibles pour estimer le poids brut, le pourcentage de femelles et la fécondité des stocks de saumon atlantique dans les rivières du secteur de la baie St-George, dans la portion insulaire de Terre-Neuve, ont été examinées. De nouvelles estimations des caractéristiques biologiques de ces stocks, lesquelles incluent les données recueillies depuis le moratoire, ont été comparées aux valeurs actuellement utilisées pour déterminer l'état de ces stocks. En général, les nouvelles estimations du poids brut et du pourcentage de femelles sont moins élevées que les valeurs par défaut actuelles. La nouvelle estimation de la fécondité pour les petits saumons (<63 cm) (1880 œufs/kg) est plus élevée que la valeur par défaut actuelle de 1540 œufs/kg. Pour les rivières étudiées en 2008, les nouvelles valeurs ont entraîné une hausse du pourcentage de conservation obtenu pour la rivière Harry's et le ruisseau Middle Barachois et un déclin pour le ruisseau Flat Bay, la rivière Fischell et la rivière Robinsons. Dans l'ensemble, il manque des données biologiques spécifiques aux rivières et aux années, notamment des données sur la fécondité pour ces rivières. L'amélioration des estimations du pourcentage de conservation obtenu ne pourra se faire qu'avec un échantillonnage additionnel de ces populations.

INTRODUCTION

The conservation status of Atlantic salmon in Newfoundland and Labrador is assessed on a river by river basis. It is determined by estimating the number of eggs deposited by female fish in a given watershed. Each watershed has a pre-determined egg deposition target. If that target is achieved the river is deemed to be at 100% conservation, and therefore, the salmon population is at a lower probability of being extirpated than if the population had not achieved 100% conservation.

To calculate the number of eggs deposited in a watershed requires three key pieces of information. First, an estimate of the number of fish reaching the spawning grounds (spawning escapement); second, the percentage of the spawning escapement that are females (percent females); and third, the number of eggs per female (fecundity). Generally the mean weight or length of the females is used as a proxy for fecundity because the number of eggs per female is size dependent (Porter and Bourgeois 1998; Bourgeois et al. 1999).

Ideally, the data described above would be collected each year for each river on which an assessment was to be conducted. However, collecting enough fish to produce a representative sample on each river annually is not practical. Furthermore, fecundity data require either sacrificing the fish or stripping the fish just prior to spawning. Given the decline in large (≥63cm) salmon especially multi sea winter (MSW) fish, neither method is very desireable. Therefore, when year specific or river specific biological data are not available the values necessary to assess the status of the stock are compiled from multiple years on the same river, or multiple years from multiple rivers to produce average values of weight, percent female, fecundity, etc.

For example, Reddin and Mullins (1996) compiled data from 11 rivers in the Bay St. George area using this type of method and produced the values that are currently used in DFO stock assessments for Bay St. George (BSG) rivers (Porter and Bourgeous 1998). However, Reddin and Mullins (1996) only had data collected up to and including 1994 which meant that their estimates of whole weight and percent female during the moratorium years (1992-94) were based on a very small sample size. The moratorium on the Atlantic salmon commercial fishery that started in 1992 had the potential to dramatically alter the biological characteristics of the in-river populations given that the commercial fishery targeted larger fish. As well, the default value for fecundity for all BSG rivers, with the exception of Flat Bay Brook, is based on a single study carried out in 1968 (Sturge 1968). Since the Sturge (1968) study, other estimates of fecundity for Newfoundland rivers have been published (Porter and Bourgeois 1998; Bourgeois et al. 1999; O'Connell et al. 2008) Therefore, it was decided to revisit the available data from 1992 to 2009 to compare more recent data with currently accepted estimates of whole weight, percent females and fecundity and to determine if the current values for the BSG rivers should be updated.

METHOD

WEIGHT AND PERCENT FEMALES

To estimate mean weight and percent females in the BSG populations, the same basic method used by Reddin and Mullins (1996) was employed. First, the number of fish sampled each year on each river since 1992 was compiled (Tables 1-4). If the number of fish sampled on a specific river in a particular year was greater than or equal to 30 then year specific and river specific values would be used in the assessment for that year (Category = Year). If less than 30

samples were collected in a particular year then all the samples available since 1992 would be compiled. If there were 30 or more samples collected on a specific river since 1992 then the average weight and percent females from those data would be used to produce a "river mean" to be used in the assessment. If less than 30 samples were available then all available samples (pre and post 1992) for that river would be included in the means (Category = River either pre or post 1992). If less than 30 samples for a specific river were available in the DFO database then an "all Bay St. George" mean value for weight and percent female would be calculated and used in the assessment for that river (category = All BSG). This hierarchical approach was applied to small and large salmon separately

FECUNDITY

Only one data set exists for fecundity in BSG. In the fall of 1995 and 1996 eggs were removed from female fish from Flat Bay Brook and counted. The resulting straight-line relationship between length and number of eggs (Porter and Bourgeois 1998) was:

Number of eggs = 173.02 * Fork length (cm) - 6266.8

For comparison purposes the eggs/cm were converted to eggs/kg based on the mean length and weight of Flat Bay Brook fish. The values used were 53 cm and 1.43 kg, and 71 cm and 3.41 kg for small and large fish respectively.

Because only one fecundity data set exists for BSG rivers, applying the same hierarchical approach for estimating fecundity as was used for estimating weights and percent females results in using the Flat Bay Brook fecundity data for all of the BSG rivers (category = All BSG). To offset some of this bias, rather than using the mean weight from Flat Bay Brook fish as a proxy for all BSG rivers, a length weight relationship was developed for BSG rivers based on the annual mean weights and lengths from all BSG salmon collected since 1992 (Fig 1.). The fecundity (eggs/kg) then, for all BSG fish was estimated based on the Flat Bay Brook fecundity data and by converting length (53 cm and 71 cm) to weight using the power function equation given in Figure 1.

RESULTS AND DISCUSSION

The proposed new values for mean weight, percent females, and fecundity for BSG rivers to be used in future assessments are given in Tables 5 and 6. With the exception of Harry's River, very few rivers had enough samples within a single year or since the moratorium to allow river specific values to be used. This was especially true for large fish. The new values for fecundity of 1880 eggs/kg for small salmon and 1570 eggs/kg for large salmon were derived solely from egg collections on Flat Bay Brook. It can be argued that any one river is not representative of all rivers in a geographic area. However, collecting river specific data is not always practical and other biological characteristic data are treated similarly. A precedent for using index rivers already exists for the Northern Peninsula. A fecundity value derived from Western Arm Brook salmon (1783 eggs/kg) has been applied to Torrent River and Lomond River.

Since Sturge (1968), various estimates of fecundity in Newfoundland Rivers have been published (Porter and Bourgeois 1998; Bourgeois et al. 1999; O'Connell et al. 2008). Comparing only fecundity values resulting from stripping of small fish in the fall produces a range of values for Newfoundland rivers of 1731 eggs/kg (Exploits River; O'Connell et al 2008) to 2100 eggs/kg (Rocky River; Bourgeois et al. 1999). The proposed new value for small salmon in BSG rivers

of 1880 eggs/kg is within this range and in line with values currently used in assessments (Table 7). The 1540 eggs/kg reported by Sturge (1968) was not within this range. Further, Indian River where the Sturge (1968) samples originated was re-sampled in 1984 and 1985. The resulting fecundity values produced were 2019 and 1998 eggs/kg (O'Connell et al. 2008), both of which are well above 1540 eggs/kg currently used to assess BSG rivers. It is clear from the current data that 1540 eggs/kg is not the best available estimate of fecundity in small salmon for any Newfoundland River.

For large salmon the 1540 reported by Sturge (1968) is essentially unchanged with this new methodology. However, had Sturge (1968) distinguished between large and small salmon then the fecundity value for large salmon would have decreased. This is due to the fact that even though the total number of eggs increases as female salmon increase in length, the number of eggs/kg decreases.

In 1998 Middle Barachois Brook had enough large salmon collected to meet the criteria (30 fish) to use a river specific value for percent female (Table 4). The value calculated was 94 % (31of 33 fish). Given that this sample was taken on one occasion in August and from one section of the river (Porter 2000) the result may not be accurate. Moreover no other sampling in BSG, with an n greater than 5, has produced such a high percentage of females in either the large or small category (Tables 3 and 4) and the BSG mean for larger females is 65 %. Given the lack of confidence in the estimate of 94% females it seems unreasonable to assign that value to the Middle Barachois River. Therefore, it was decided to use the BSG mean of 65% large females for Middle Barachois Brook (Table 6).

Table 8 shows a comparison between the current values used in the 2008 assessment of salmon stocks in the BSG rivers for which counts were available, and the suggested new values. The data in Table 8 suggests that DFO has been overestimating the mean weights and percent females in the population and underestimating the number of eggs/kg. The difference in percent conservation between the current values and the proposed new values is shown in Table 9. Adopting the new values results in an increase in the estimate of total eggs deposited and hence percent conservation met in Harry's River and Middle Barachois Brook but a decline in other rivers. This difference is driven primarily by the large decrease in the estimate of percent female for many of the rivers. The sex of the fish is generally determined by external features in the spring and summer when the counting fences are in operation. This method may not be the most accurate way of determining sex. Additional work is needed to measure the accuracy of this technique.

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Table 1. Number of small (< 63 cm) male (M) and female (F) Atlantic salmon weighed between 1992 and 2008 on Bay St. George rivers. High = Highlands R; Crab = Crabbes R; Mbar = Middle Barachois Bk; Rob = Robinsons R; Fis = Fishels R; FlB = Flat Bay Bk; SWB = Southwest and Bottom Bk; Har = Harry's R; Rom = Romaines R.

	River															
	High		Crab		MBar		Rob		Fis		FlB		SWB		Har		Rom	
Year	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1992							1	1								1		
1993							1								8	36		
1994											2	1			11	36	1	8
1995											23	60			12	31	3	36
1996											59	93						
1997															19	34		
1998					32	39									22	44		
1999		1													2	5		
2000							20	8			12	13			15	36		
2001							21	22	2		17	25			2	11		
2002					2	2			6	9					15	40		
2003							12	6							23	24		
2004							4	12							28	94		
2005			3	5														
2006																		
2007															9	52		
2008															12	50		
2009															7	56		

Table 2. Number of large (≥63 cm) male (M) and female (F) Atlantic salmon weighed between 1992 and 2008 on Bay St. George rivers. High = Highlands R; Crab = Crabbes R; Mbar = Middle Barachois Bk; Rob = Robinsons R; Fis = Fishels R; FlB = Flat Bay Bk; SWB = Southwest and Bottom Bk; Har = Harry's R; Rom = Romaines R.

	River															
	High		Crab		MBar		Rob		Fis		FlB		SWB		Har		Rom	
Year	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1992																		
1993																2		
1994																		3
1995											1	3				1		3
1996											9	15						
1997															2			
1998					2	32									3	5		
1999																		
2000															2	3		
2001							1											
2002															2	4		
2003															3	3		
2004																		
2005				1														
2006																		
2007															14	25		
2008															11	37		
2009															12	33		

Table 3. Number of small (< 63 cm) Atlantic salmon sexed between 1992 and 2008 on Bay St. George rivers. n = sample size; %F = Percent females in sample. High = Highlands R; Crab = Crabbes R; Mbar = Middle Barachois Bk; Rob = Robinsons R; Fis = Fishels R; FIB = Flat Bay Bk; SWB = Southwest and Bottom Bk; Har = Harry's R; Rom = Romaines R.

	River																			
	High		Crab		MBar		Rob		Fis		FIB		SWB		Har		Rom	
Year	n	%F	n	%F	n	%F	n	%F	n	%F	n	%F	n	%F	n	%F	n	%F
1992							5	60					7	71	63	65		
1993							6	50					9	67	53	77		
1994											4	50			49	78	12	83
1995	13	46									83	72			43	72	43	78
1996	19	79									153	61						
1997	15	67													53	64		
1998	9	67													68	66		
1999	16	75													7	71		
2000							38	29			32	56			51	71		
2001							53	55	3	0	56	59			13	85		
2002					74	54	4	75	15	60					55	73		
2003							24	29							47	51		
2004							16	75							122	77		
2005			8	62											35	71		
2006															63	73		
2007															61	85		
2008															62	81		
2009															63	89		

Table 4. Number of large (≥63 cm) Atlantic salmon sexed between 1992 and 2008 on Bay St. George rivers. n = sample size; %F = Percent females in sample. High = Highlands R; Crab = Crabbes R; Mbar = Middle Barachois Bk; Rob = Robinsons R; Fis = Fishels R; FIB = Flat Bay Bk; SWB = Southwest and Bottom Bk; Har = Harry's R; Rom = Romaines R.

	River																	
	High		Crab		MBar		Rob		Fis		FIB		SWB		Har		Rom	
Year	n	%F	n	%F	n	%F	n	%F	n	%F	n	%F	n	%F	n	%F	n	%F
1992																		
1993															5	100		
1994																	3	100
1995	11	36									4	75			1	100	3	100
1996	14	86									24	62						
1997	2	50													3	0		
1998	12	33			33	94									8	62		
1999	11	64																
2000															5	60		
2001							1	0										
2002															6	67		
2003															6	50		
2004																		
2005			1	100											50	62		
2006															51	57		
2007															39	64		
2008															48	77		
2009															45	73		

Table 5. New values for small salmon. Category indicates the grouping from which the value was calculated. High = Highlands R; Crab = Crabbes R; Mbar = Middle Barachois Bk; Rob = Robinsons R; Fis = Fishels R; FIB = Flat Bay Bk; SWB = Southwest and Bottom Bk; Har08 = Harry's R 2008; Har09 = Harry's R 2009; Rom = Romaines R.

River	WW (kg)	Category	%Female	Category	Fecundity (eggs/kg)	Category
High	1.54	All BSG	68	River	1880	All BSG
Crab	1.48	River	52	River	1880	All BSG
M Bar	1.46	River	54	River	1880	All BSG
Rob	1.49	River	47	River	1880	All BSG
Fis	1.42	River	49	River	1880	All BSG
Fl B	1.43	River	63	River	2000	River
SW B	1.30	River	51	River	1880	All BSG
Har08	1.60	Year	81	Year	1880	All BSG
Har09	1.84	Year	89	Year	1880	All BSG
Rom	1.38	River	89	River	1880	All BSG

Table 6. New values for large salmon. Category indicates the grouping from which the value was calculated. High = Highlands R; Crab = Crabbes R; Mbar = Middle Barachois Bk; Rob = Robinsons R; Fis = Fishels R; FIB = Flat Bay Bk; SWB = Southwest and Bottom Bk; Har08 = Harry's R 2008; Har09 = Harry's R 2009; Rom = Romaines R.

River	WW (kg)	Category	%Female	Category	Fecundity (eggs/kg)	Category
High	4.18	All BSG	58	River	1570	All BSG
Crab	4.18	All BSG	65	All BSG	1570	All BSG
M Bar	4.18	All BSG	65	All BSG	1570	All BSG
Rob	4.18	All BSG	65	All BSG	1570	All BSG
Fis	4.18	All BSG	65	All BSG	1570	All BSG
Fl B	4.18	All BSG	65	All BSG	1700	River
SW B	4.18	All BSG	65	All BSG	1570	All BSG
Har08	4.57	Year	77	Year	1570	All BSG
Har09	4.46	Year	73	Year	1570	All BSG
Rom	4.18	All BSG	65	All BSG	1570	All BSG

Table7 . List of fecundity values used in Atlantic salmon stock assessments in Newfoundland rivers.

River	Eggs/kg	Eggs/cm
Northeast River (Placentia)	2352	
Rocky	2100	58.7
Campbellton	2100	
Flat Bay	2027	54.7
Middle Brook	1980	
Conne	1906	47.9
Western Arm Brook	1783	
Lomond River	1783	
Torrent River	1783	
Northwest River (Port Blandford)	1767	
Terra Nova	1761	
Expliots	1759	46
Gander River	1752	
Harry's River	1540	

Table 8. Comparison of current values (cur) used in 2008 stock assessments and proposed new values. M Bar = Middle Barachois Bk; Rob = Robinsons R; Fis = Fishels R; F IB = Flat Bay Bk; Har = Harry's R.

River	WW (kg)				%Female				Fecundity (eggs/kg)			
	Small		Large		Small		Large		Small		Large	
	cur	new	cur	new	cur	new	cur	new	cur	new	cur	new
M Bar	1.46	1.46	2.94	4.18	54	54	94	65	1540	1880	1540	1570
Rob	1.63	1.49	5.06	4.18	72	47	87	65	1540	1880	1540	1570
Fis	1.63	1.42	5.06	4.18	72	49	87	65	1540	1880	1540	1570
Fl B	1.34	1.43	3.31	4.18	72	63	67	65	2027	2000	1719	1700
Har 08*	1.60	1.60	5.06	4.57	81	81	87	77	1540	1880	1540	1570
Har 09*	1.84	1.84	5.06	4.46	89	89	87	73	1540	1880	1540	1570

* Har 08 = Harry's River 2008 data; Har 09 = Harry's River 2009 data

Table 9. Comparison of current estimate of stock status (2008) and new assessment. M Bar = Middle Barachois Bk; Rob = Robinsons R; Fis = Fishels R; F IB = Flat Bay Bk; Har = Harry's R.

River	% Conservation Achieved		% Change
	Current	New	
M Bar	28	35	24
Rob	108	77	-29
Fis	99	70	-29
Fl B	125	110	-12
Har 08*	108	119	11
Har 09p*	90	96	6

* Har 08 = Harry's River 2008 data; Har 09p = Harry's River 2009 preliminary data

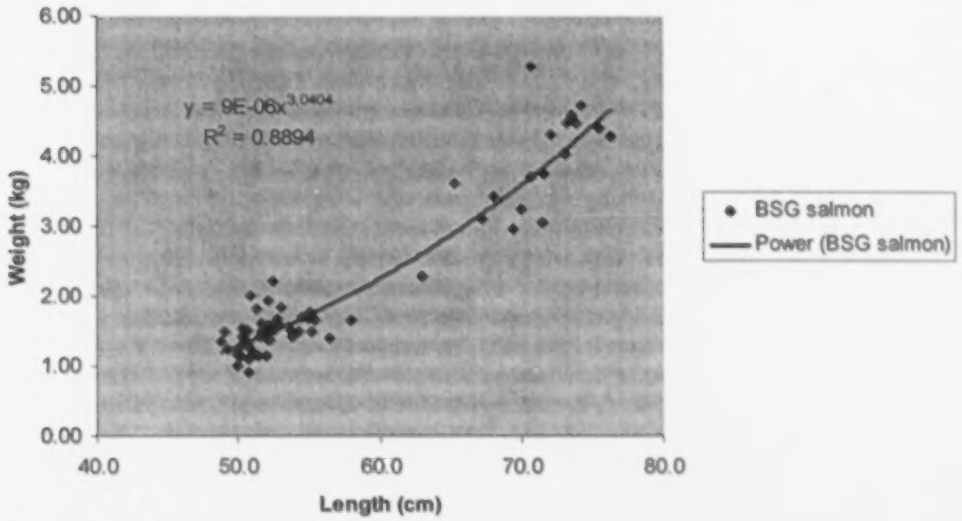

Figure 1 Relationship between annual mean lengths and annual mean weights for Atlantic salmon sampled in BSG rivers from 1992-2008.